

¹
02
N68-17481

OPEN-ACCESS C.W. DOPPLER TECHNIQUE
FOR COLLISION-HAZARD WARNING

James H. Schrader

Page 7
Code +

HC \$3.00
MF 465

(Presentation at FAA-Sponsored Symposium on Pilot Warning Indicators
for Aircraft Collision Avoidance; December 12, 1967)

Langley Research Center has been investigating techniques which can be applied to the collision-hazard problem for general aviation. As has been indicated previously, the ideal device is one which is, first, self-contained; second, inexpensive; third, lightweight; and, fourth, low powered. However, since we were not able to find an approach which would satisfy all these requirements, it appeared necessary to concentrate on what was probably the most important goal in that it determines the degree of acceptance or use - that of cost. Following a review of the work which has been done previously on the initiative of FAA and industry, we initiated the investigation of a relatively simple, cooperative, CW doppler technique which employs random coding to permit a number of aircraft to simultaneously interrogate a simple transponder. To the best of our knowledge this approach has not been considered previously.

The basic concept of this approach is shown on the next slide. The protected aircraft transmits a pair of frequency modulated signals of f_1 and f_2 . These signals are received at the intruding aircraft and multiplied to derive a signal at the instantaneous difference frequency. This signal is then retransmitted to the protected aircraft where it is received and compared to the instantaneous difference in the transmitted pair to derive the doppler shift. The signal strength received at the protected aircraft will vary inversely as the sixth power of range. This is due to the squared variation in the transmission, the square relationship in the multiplier, and the squared variation

in the retransmission. There are two basic parameters, therefore, that can be used in deriving a warning. First, the variation in signal level, 60 dB for a decade change in range; and second, the variation in frequency proportional to closing velocity. Various combinations of these parameters can, of course, provide a warning threshold based on time-to-closest-approach and/or range.

The next figure simply shows functionally what is required to implement this approach; at the top I have shown the transmitter assembly. The transmitted pair can be derived by the mixing of two frequency modulated signals to obtain the sum and difference frequencies. The advantages of this arrangement are two-fold, first; the lower oscillator is then related to the retransmission frequency (f_3) and can be used in the receiver, and second; the modulation characteristics of the retransmitted frequency (f_3) can be controlled directly at this oscillator. Controlling the modulation of these oscillators controls the degree of suppression obtained at this receiver with respect to cross-products or other retransmitted signals. The transmitted signals should be on the order of a watt. These transmitted signals are received at the transponder, amplified and mixed to derive the difference frequency, which is amplified and retransmitted to the receiver. Basically, the receiver instantaneously compares the received signal frequency with the difference of the transmitted pair as indicated by the lower oscillator. This comparison can be implemented as shown, by the conversion of the input signal to an intermediate frequency, where a ssb filter selects signals modified by an approaching doppler term and rejects those modified by a receding doppler term, and then conversion to the doppler frequency. Additional processing can then be employed to provide a

warning based on amplitude and frequency (range and closing velocity).

The final figure summarizes what appear to be the advantages and limitations of this technique. First, it should be adaptable to various degrees of protection since the power levels may be different for different detection ranges, and various types of processing of the received signal may be incorporated, such as multiple target separation and direction angle detection. Second, individual channel assignments for each aircraft are not required. Third, since it is a coherent doppler system, precise frequency control is not required. Fourth, because it is a relatively simple system, the cost should not be extremely high.

Of course, there are limitations. First, since separation of returns is accomplished on the basis of frequency, two aircraft with identical closing velocities are not separable. I'd like to point out, however, that any maneuver that the protected aircraft makes should separate the closing velocities. A separation of on the order of 10 knots is required. Second, since the range approximation is based on signal level, it will not be too accurate. For instance, 18 dB total variation in net gain results in range accuracies of ± 33 percent. Finally, since the system is a CW system where the total transponder power is a function of the number of aircraft as well as the range, it may be saturated. I'd like to point out here that, due to the range limiting feature, this saturation will have to occur due to local aircraft densities, that is, a dense situation within a 5 to 10 miles diameter.

To conclude, Langley is investigating this technique as one possible approach to the collision-hazard warning problem. Our work has not developed to the point where we can define the detailed performance of various equipment configurations or their cost in dollars. You can see, however, that the

transponder which would be needed on all aircraft is relatively simple with the major items being the antenna and a linear amplifier. We are continuing performance analyses of this concept with particular attention to the saturation problem, and are also investigating some of the practical implementation problems.

SYSTEM CONCEPT

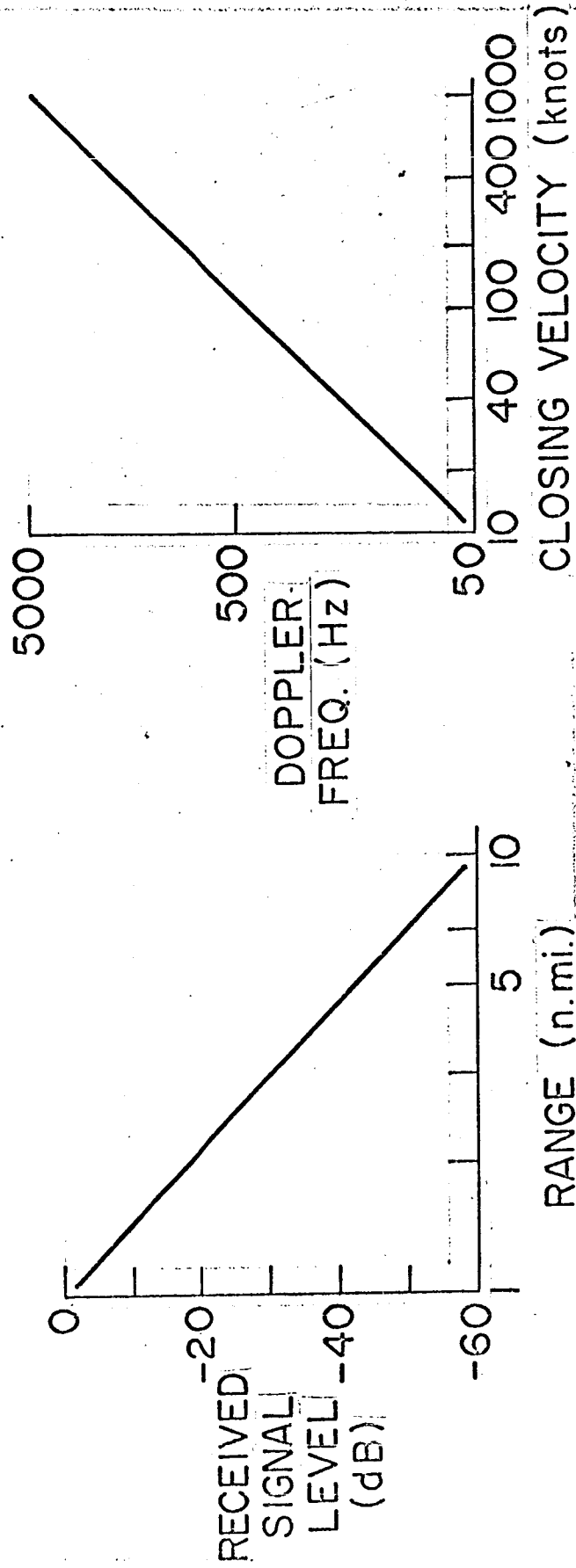
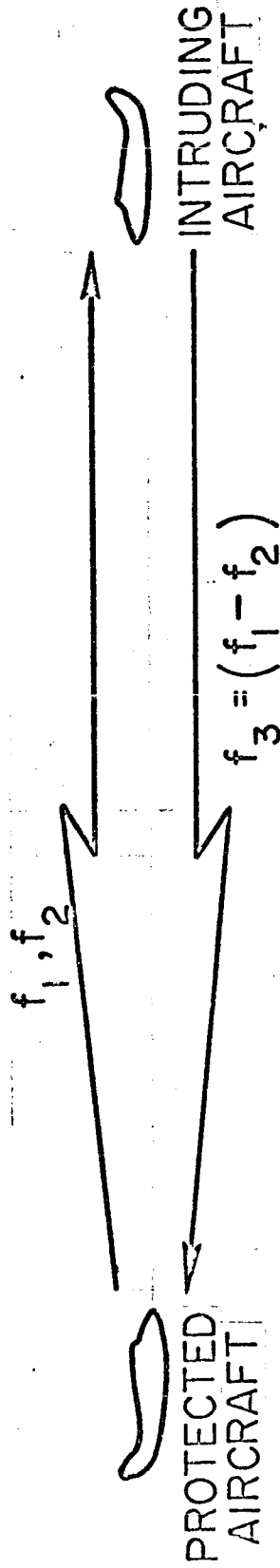
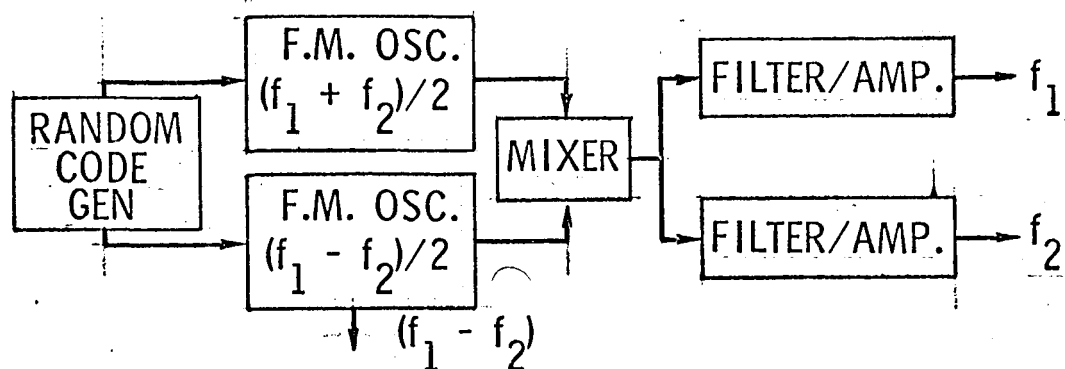
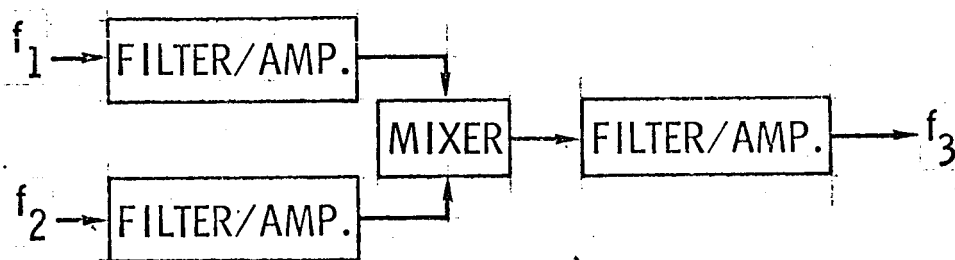


FIGURE 1

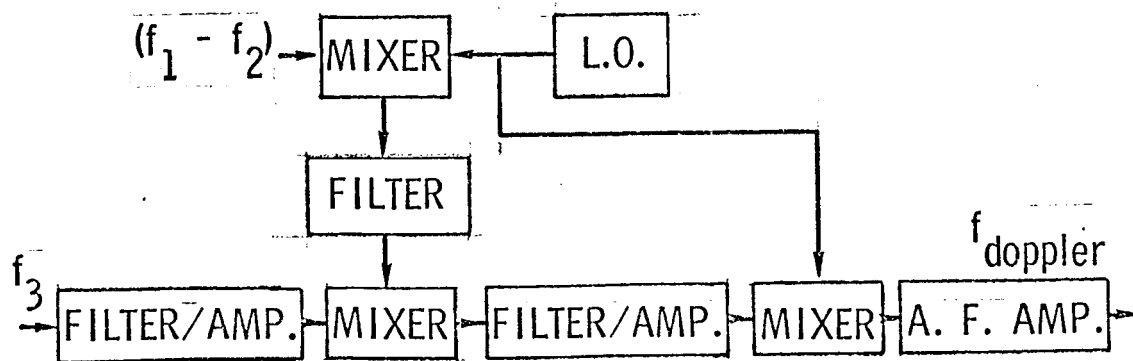
FUNCTIONAL DIAGRAM



TRANSMITTER



TRANSPONDER



RECEIVER

ADVANTAGES

1. ADAPTABLE TO VARIOUS DEGREES OF PROTECTION.
2. INDIVIDUAL CHANNEL ASSIGNMENTS NOT REQUIRED.
3. PRECISION CONTROL OF FREQUENCY NOT REQUIRED.
4. RELATIVELY LOW COST.

LIMITATIONS

1. RETURNS FROM MULTIPLE AIRCRAFT WITH IDENTICAL CLOSING VELOCITIES ARE NOT SEPARABLE.
2. ACCURACY OF RANGE DETERMINATION.
3. POSSIBLE SYSTEM SATURATION.

FIGURE 3

12/67